THE CHARACTERIZATION OF ELECTROPLATED Cr COATING

Maroš MARTINKOVIČ, Daniel KOTTFER,
Milan FERDINANDY, Ildikó MAŇKOVÁ

Authors: ***Maroš Martinkovič, Assoc. Prof. PhD.,* Daniel Kottfer, PhD.,** Milan Ferdinandy, RNDr.,***Ildikó Maňková, Prof. PhD.*****
Workplace: **** Faculty of Materials Science and Technology in Trnava, Slovak University of Technology Bratislava***
***** Faculty of Mechanical Engineering, Technical University in Košice***
****** Institute of Materials Research, Slovac Academy of Science***
Address: **** Pavlínska 16, 917 24 Trnava, Slovak Republic***
***** Mäsiarska 74, 040 01 Košice, Slovak Republic***
****** Watsonova 47, 040 01 Košice, Slovak Republic***
Phone: ***+421 906068345***
E-mail: ***maroš.martinkovič@stuba.sk; daniel.kottfer@tuke.sk; mferdinandy@imr.saske.sk; ildiko.mankova@tuke.sk***

Abstract

The conventional chromium layers were prepared on a steel substrate OCHN3 MFA by specific conditions. Their thickness, chemical composition, hardness, wear resistance and abrasion coefficient were compared with data from scientific literature obtained under other conditions than by the experiment

Key words

mechanical properties, electroplated coatings, wear

Introduction

Electroplated Cr coatings are widely used for functional purposes in the automotive, aerospace and manufacturing industries [1]. Due to their properties such as the strong adhesive ability with substrate, high hardness and excellent wear and corrosion resistance [1-4] electroplated Cr coatings can be used in almost any situation where resistance to abrasion wear is vital. Some areas of application [1]: *Automotive:* shock-absorber rods; power steering shaft; Mac Pherson struts; valve stems; crankshafts; camshafts, *Aircraft:* rocker arms; turbine blades; crankshafts; cylinders; camshaft journals; undercarriage rams; piston rings; landing gear shafts; valves, *Fluid power engineering:* oil hydraulic compressor cranks; oil hydraulic cylinders; oil hydraulic piston a rods; oil hydraulic rams; oil hydraulic valves; turbine blades; turbine distributor blades; turbine shafts, *Ordnance:* gun barrels.

Hard chromium plating is usually used to restore the original dimensions of worn surfaces of the shafts, pumps and compressors [3, 4]. However, over the last decade, there has been an increasing concern surrounding the processing of chromium coatings using electroplating. This is due to environmental, health and safety considerations associated with the handling, storage and disposal of hexavalent chromium (Cr^{6+}) compounds normally used during the plating process.

There exist many materials and technologies for coating as a substitute for the conventional Cr^{6+} electroplated coating. One substitute technology is HVOF, PVD. Other alternatives to conventional chromium coatings are coatings deposited from a 3-valent chromium bath [1] and CrN coatings deposited by PVD techniques [5]. Coatings deposited by thermal spraying also appear as alternatives to hard chromium plating [9].

Zeng [6] evaluated the correlation between the hardness and tribological behaviour of electroplated Cr coatings sliding against ceramic and steel counterparts. The Cr layer evaluated was deposited at the deposition current density *60 A/dm²* and the temperature *55 °C*. Thickness of the Cr coating was *50 μm*. Evaluated properties: the micro hardness and the wear resistance. Zeng [7] also evaluated tribological and electrochemical behaviour of thick CrC coatings electrodeposited in a trivalent chromium bath as an alternative to conventional Cr coatings. The CrC coating was deposited on steel and copper substrates by direct current deposition process. The conventional Cr coating was prepared from a Sargent bath with a current density of $60\ Adm^{-2}$ at *55°C*. The structure of the CrC alloy and conventional Cr coating by XRD technique were evaluated. The surface morphology and wear track were observed by scanning electron microscopy. The wear resistance was estimated by pin-on disc test. Huang et al. [2] evaluated the electrochemical behaviour of the bright Cr deposits plated with direct- and pulse-current in 1M H2SO4. Cr coatings were electroplated at *50 °C* with current densities of $30\ A/dm^2$, $40\ A/dm^2$, $50\ A/dm^2$ and $60\ A/dm^2$. Darbeira et al. [8] calculated the wear as a variation of wear volume per unit sliding distance as a function of coating hardness in a multipass and pin-on-disc operation after 1000 passes.

The aim of the article was to expand the knowledge of Cr coating coated on steel substrate OCHN3 MFA electrolytically at a temperature and current frequency outside of the interval of the above-mentioned authors.

Preparation of substrate and Cr coating

Test samples were produced from the material OCHN3 MFA (steel), whose chemical composition is shown in Table 1. Produced from this material as listed are mainly cannons of the 2A 42 (apart from the rear section). The shape and dimensions of the test samples (Fig. 1) were selected as relating to their preparation for the pin-on-disc test.

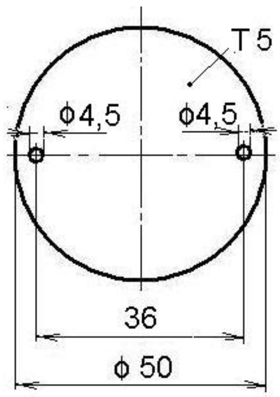


***Fig. 1** Shape of the sample for the Pin-on-disc test*
T5 – thickness of samples

CHEMICAL COMPOSITION OF OCHN3 MFA STEEL SUBSTRATES Table 1

Elem.	C	Mn	Si	Cr	Ni	Mo	S	P	Cu	Sb	V
%	0,360	0,500	0,250	0,820	2,870	0,300	0,004	0,014	0,150	0,007	0,12

Substrates were OCHN3 MFA steel plates with an area of *0,2* dm^2 and a hardness of *2,5GPa*. Before electrodeposition substrates were mechanically polished to a surface roughness of *Ra=0,45 μm* and then sequential cleanings were performed to remove contamination and 'activation' of substrates was carried out in 5 vol % HCl solution for 20 s.

Conventional Cr coating was electrodeposited from a modified bath, containing CrO_3 (*180* $g\ l^{-1}$), H_2SO_4 (*1,2 %* of the volume H_2SO_4), with a current density of *25* Adm^{-2} at *70 °C*, a time deposition *90* minutes.

Experimental procedures

The thickness and chemical composition of the Cr layer and steel substrate was determined with the aid of a Tesla BS 340 electron microscope. Before SEM (Scaning Electron Microscope) insertion, the sample was cooled in liquid N_2 and then broken so that the Cr layer was tensile strained. The fracture was observed (Fig. 2).

Wear and friction coefficient of the Cr coating on OCHN3 MFA steel was evaluated by the Pin-on-disc test under the following conditions: Si_3N_4 globule, diameter *6 mm*, speed of the globule *25 mm/s*, radius of the path distance *90 m* and temperature *20 °C*. Surface cross-section of the marks after friction of the globule (Fig.5) was measured by a profile roughness finish tester Mitutoyo Surftest 301 (Fig. 6) and then was calculated the volume decrease of Cr by multiplying the surface shown and the length of the circle. Then the volume was multiplied by the specific thickness of Cr. Then the wear rate *W* was evaluated by the equation (1) [7]:

$$W = \frac{V}{S.F} \qquad [10^{-6} mm^3/Nm], \qquad (1)$$

where *W* is wear rate [$10^{-6} mm^3/Nm$],
V - the wear volume los [mm^3],
S - the total sliding distance [m],
F - the normal load [N].

The Micro-Vickers hardness of chromium electrodeposits was measured along the cross-section on a metallographic section every *15 μm* on HPO 250 equipment. The initial incision was made at a distance of *5 μm* from the surface of the Cr layer. Measuring was at a load of *0,245 N.*

Thickness of the Cr layer was determined by observing the brittle fracture (Fig. 2). The measured thickness was *90 μm*. The chemical composition of the Cr layer and the steel substrate was evaluated with the aid of EDX analysis (Fig. 3).

Results and discussion

A *90 μm* thickness was measured compared to measured thicknesses of 15 μm [8], 23 μm [2] and *50 μm* [6, 7].

Hardness values of *820 HV 0,025* up to *1120 HV 0,025* were recorded. The measured values are in Fig. 4. Hardness values *HV 0,025* acquired at the temperature 70 °C are significantly higher than in the graph presented by Lausmann [1]. According to it, they should not be higher than *500 HV 0,025*. According to Lausmann, the maximum hardness value *1120 HV 0,025* is relevant for Cr layers produced at the temperature 52,5°C and current density 60A/dm^2. The average value of hardness we measured was *1000 HV 0,025* and is according to

[1] valid for the Cr layer produced at current density 35A/dm^2 and temperature 52,5 °C (not 70 °C).

Wear of the Cr layer Fig. 6 was $3,75.10^{-5}g$. The friction coefficient μ was *0,15* (distance *18 m*) and the maximum value $\mu=0,71$ (distance *90 m*) (Fig. 7). The measured friction coefficient value is lower than as shown by Darbeira μ=0,79 for the pin-on-disc test and normal strength test parameters 10N, globule speed 1mm/s [8]. The wear rate *W* according to the equation (1) is $W = 9,28.10^{-6}mm^3/Nm$. It is significantly more than as given by Zhixiang Zeng et al. W=0,8.$10^{-6}mm^3$/Nm [8].

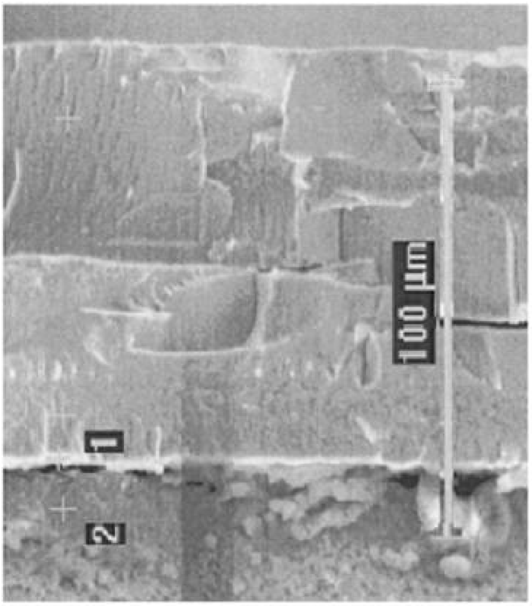
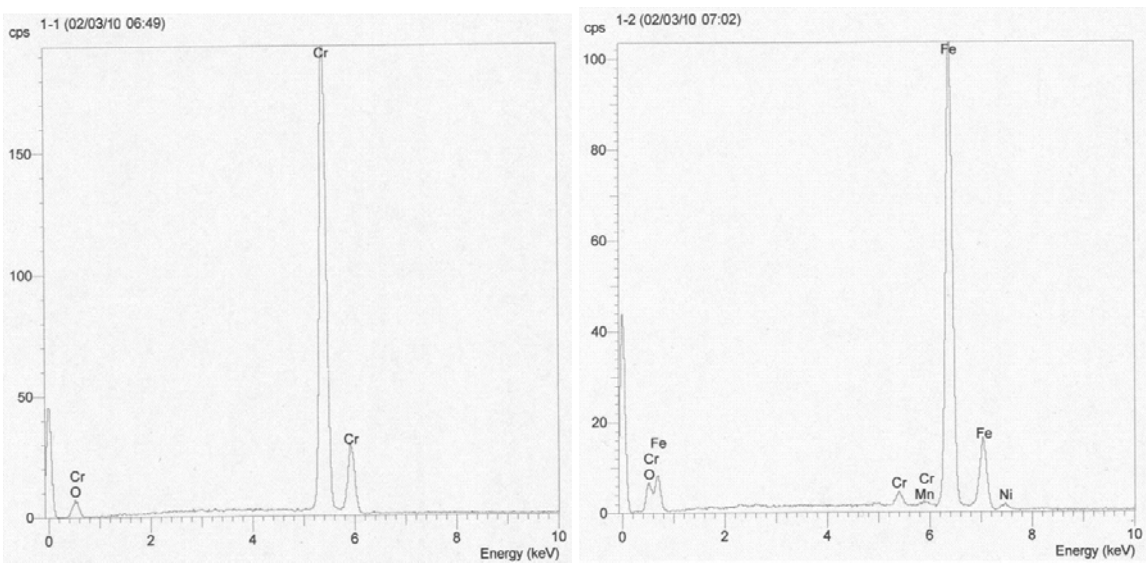


Fig. 2 *Brittle fracture of the steel substrate with Cr coating - SEM:*
1 – steel substrate, 2 – Cr coating



a) *b)*

Fig. 3 *EDX point analysis*
a) Cr layer, b) steel substrate

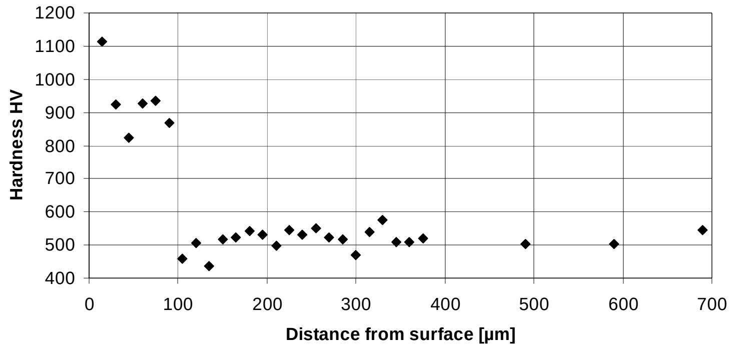


Fig. 4 *Hardness HV 0,025 measured in the direction from the surface of the Cr layer*

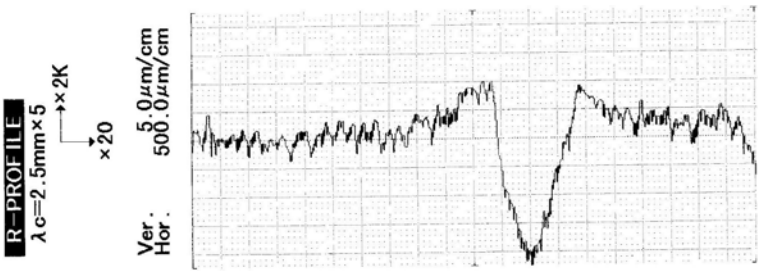


Fig. 5 *Mark after wear of the Cr layer, profilogram*

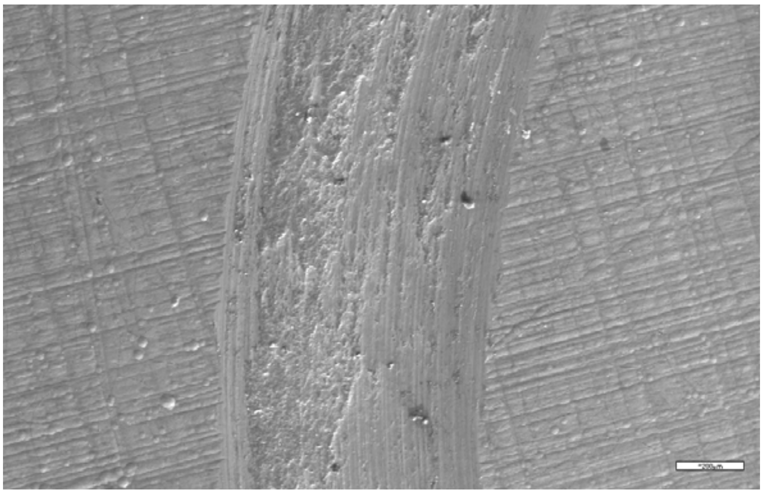


Fig. 6 *Impression after wear of the Cr layer, SEM*

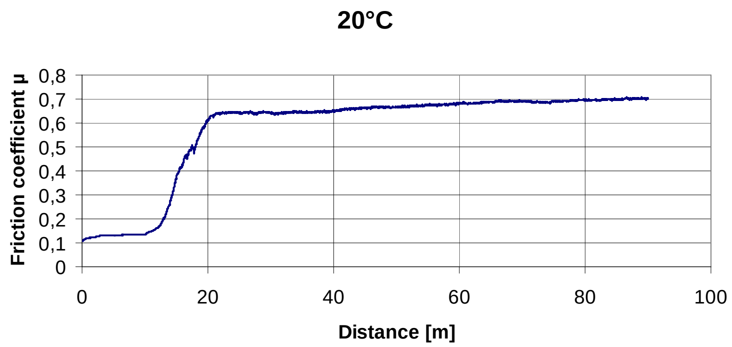


Fig. 7 *Dependence of friction coefficient on the distance*

Conclusions

The mechanical and tribological properties of the electroplated Cr coating on the OCHN3 MFA steel substrate, used in gun barrels, has been investigated and the main results are the following:

- mechanical properties as well as thickness *90 μm* Fig. 2, the hardness of the Cr coating was from *820 HV 0,025* to *1120 HV 0,025* and the hardness of the OCHN3 MFA steel substrate was from *450* to *589 HV 0,025* (Fig. 4). Determined differences are apparently connected to different experimental conditions, different thickness of Cr coatings and state of the substrates.
- the wear rate of the Cr coating is $W= 9,28.10^{-6} mm^3/Nm$. This is significantly more than given by Darbiera et al. under similar conditions of the pin-on-disc test [8].
- the friction coefficient $\mu=0,15$ (distance *18 m*) and at the maximal value of the friction coefficient $\mu=0,71$ (distance *90 m*) (Fig. 7). This is less than [8].

Acknowledgements

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